Douglas County PUD

Wells Dam
Turbine Refurbishment

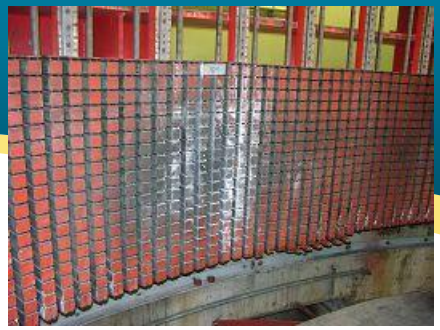
MWH®

BUILDING A BETTER WORLD

Project Background

- Commissioned 1967-1969
- Ten vertical, 5-bladed, Kaplan units
- 120,700 hp, 81.5 MVA rated generator output
- 292.25 in Runner diameter
- Original AC runners replaced in late 1980’s with Fuji runners.

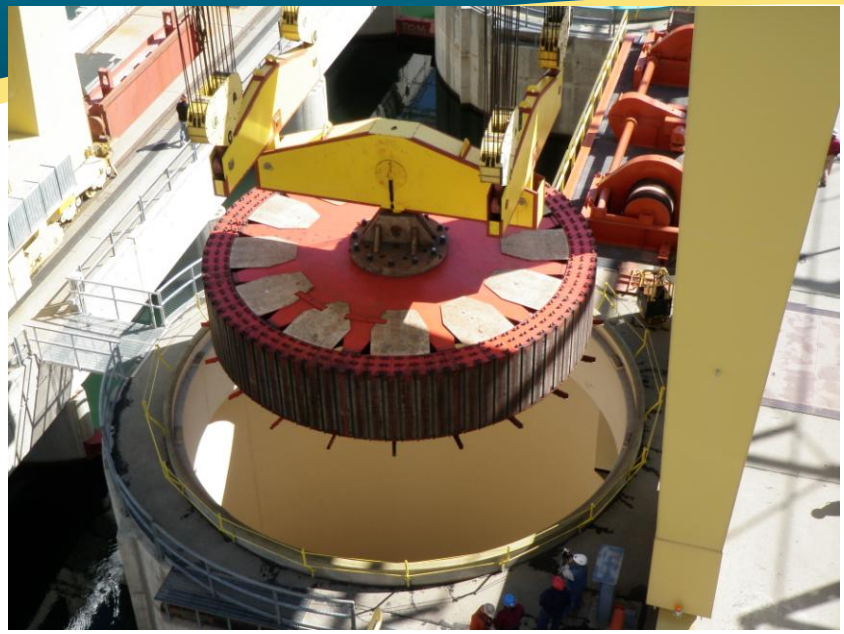
Project Background



- February 2005: Unit #1 stator failed.
- Decision made to:
  - Replace stator core and windings
  - Refubish rotor
  - Replace coolers
- Work awarded to NEC
- Completed July 2006

- Led to initiating rehab for all units to replace stators, refurbish rotors, and then refurbish turbines as necessary.

Overall Project Scope of Work

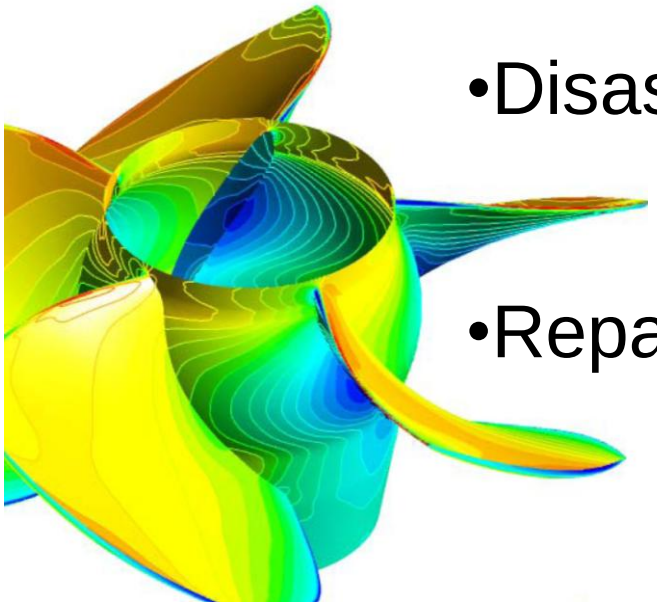


Challenge: Hydro-combine design does not have any interior laydown space for work on equipment

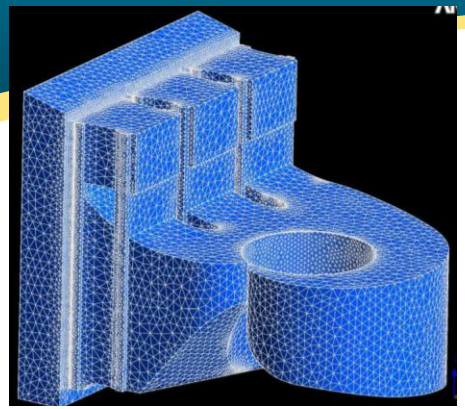
- Replace Stator
- Refurbish Rotor
- Refurbish Runner Hub
- Refurbish miscellaneous Turbine Components
- Repair and remachine Discharge Ring
- Possible Turbine improvements?

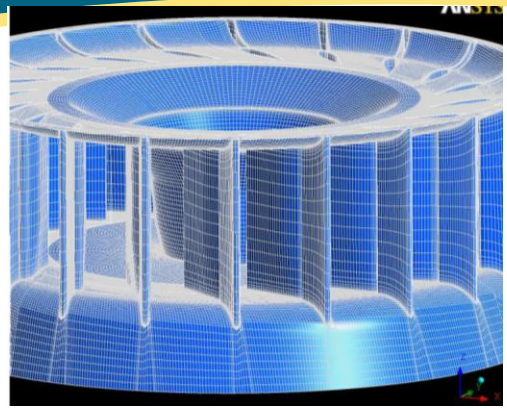
Turbine Scope of Work

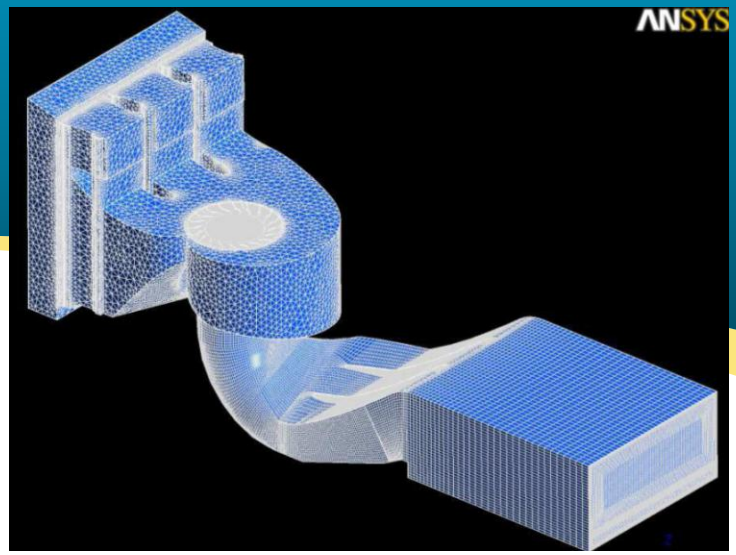
- CFD and Scale Model Testing for any efficiency gain with positive cost/benefit
- Disassembly and Inspection of Parts
- Repair Based on Inspection Findings

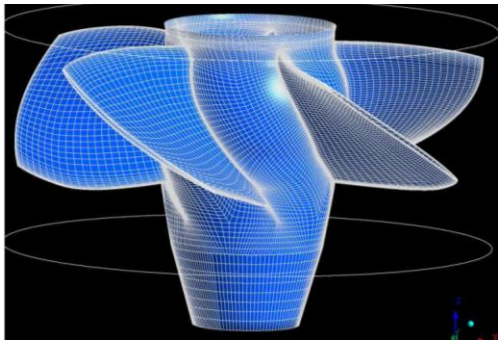


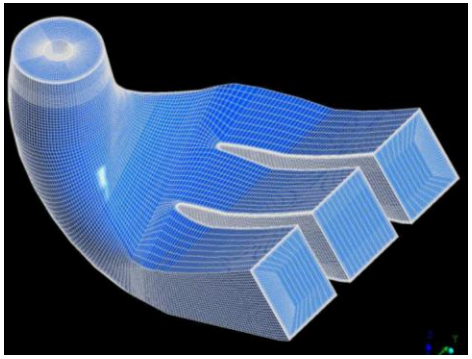
CFD Model Testing





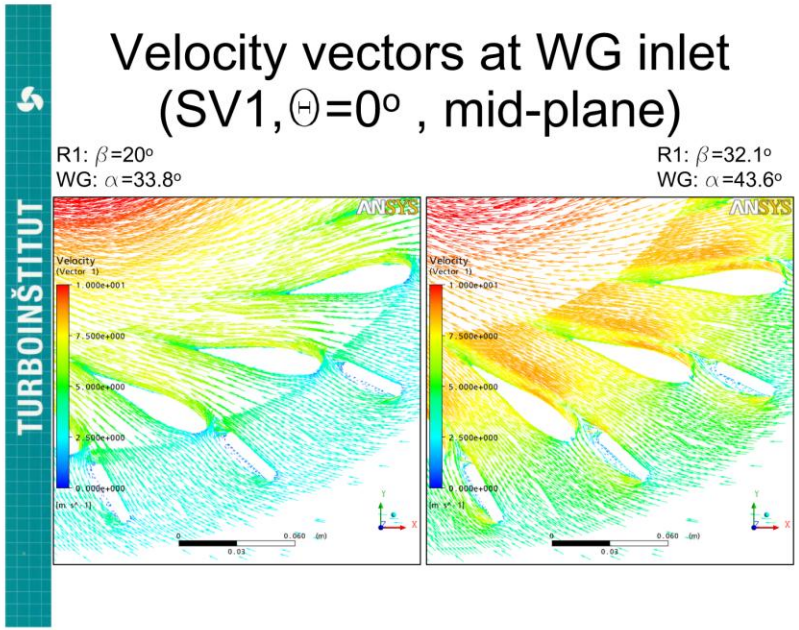


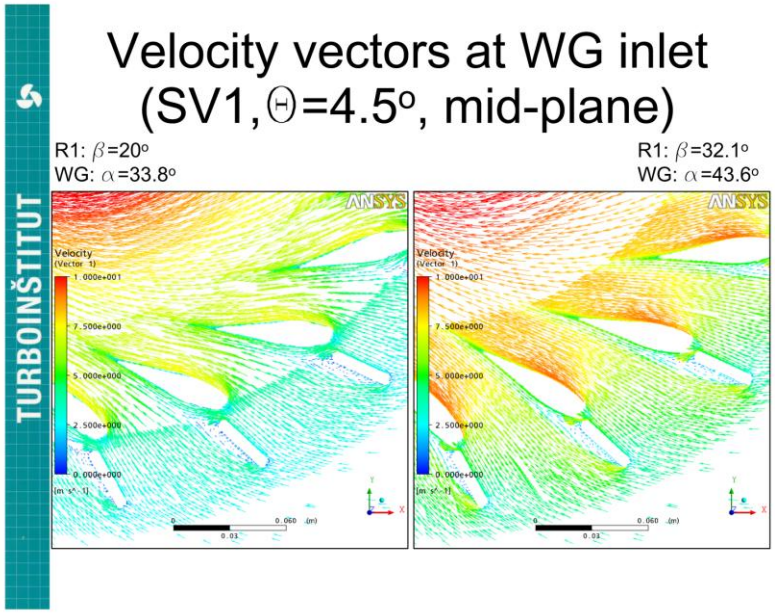


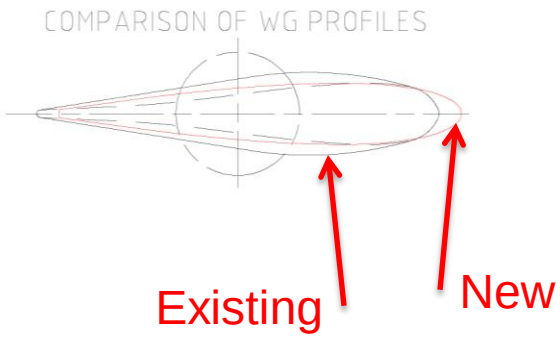


- Turboinstitute - Ljubljana, Slovenia
- CFD ModificationsTested:
  - Wicket Gate shape/rotation
  - Semi/full spherical Discharge Ring
  - Increased blade diameter
  - Draft Tube splitter vane
  - Strategic concrete in Draft Tube
  - Stay Vane shape

CFD Model Testing – Wicket Gate Shape/Rotation

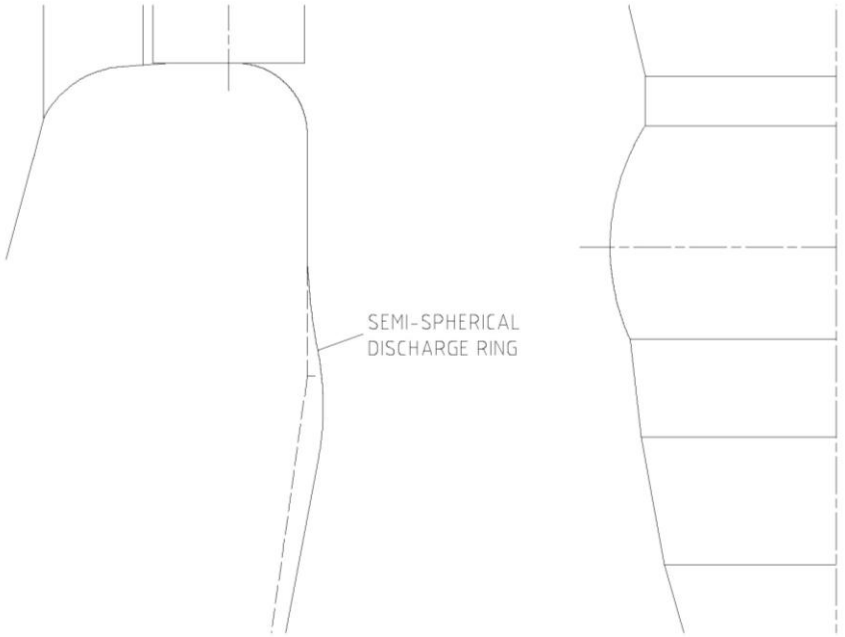




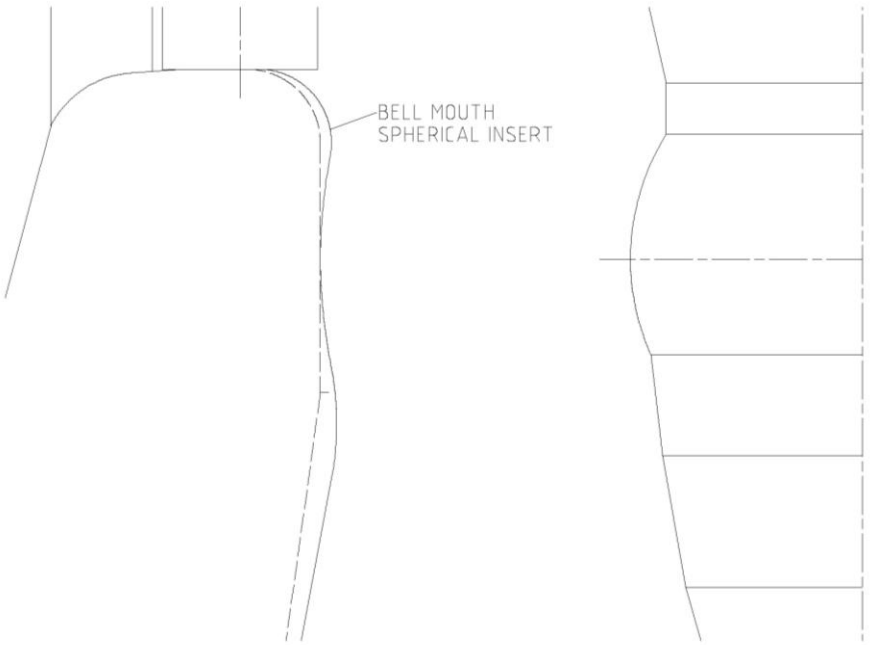


- New WG profile = no advantage
- Rotation of the WG circle by 4.5° = increased efficiency, but not cost-effective

Model Testing – Discharge Ring

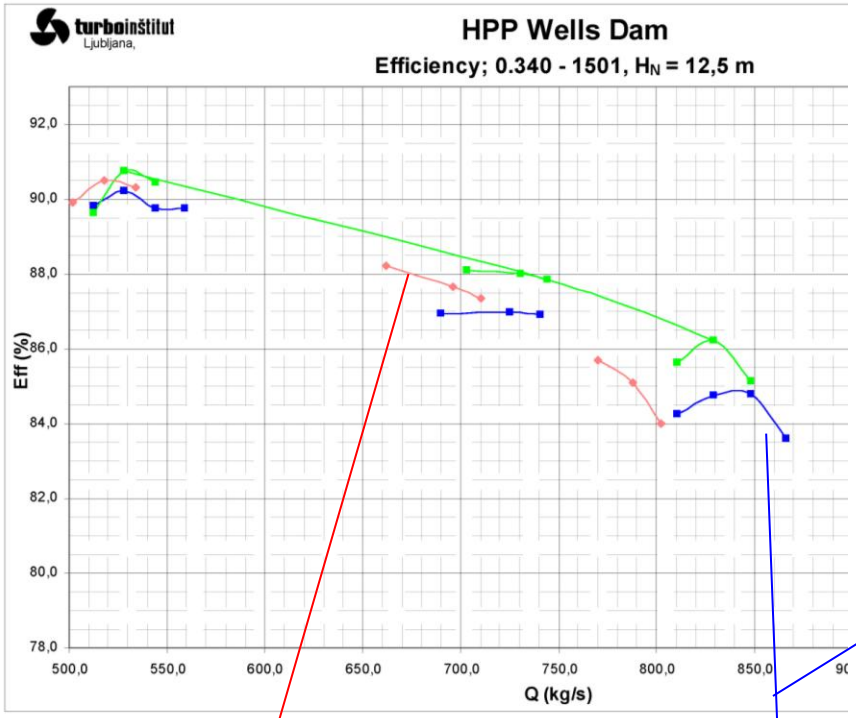


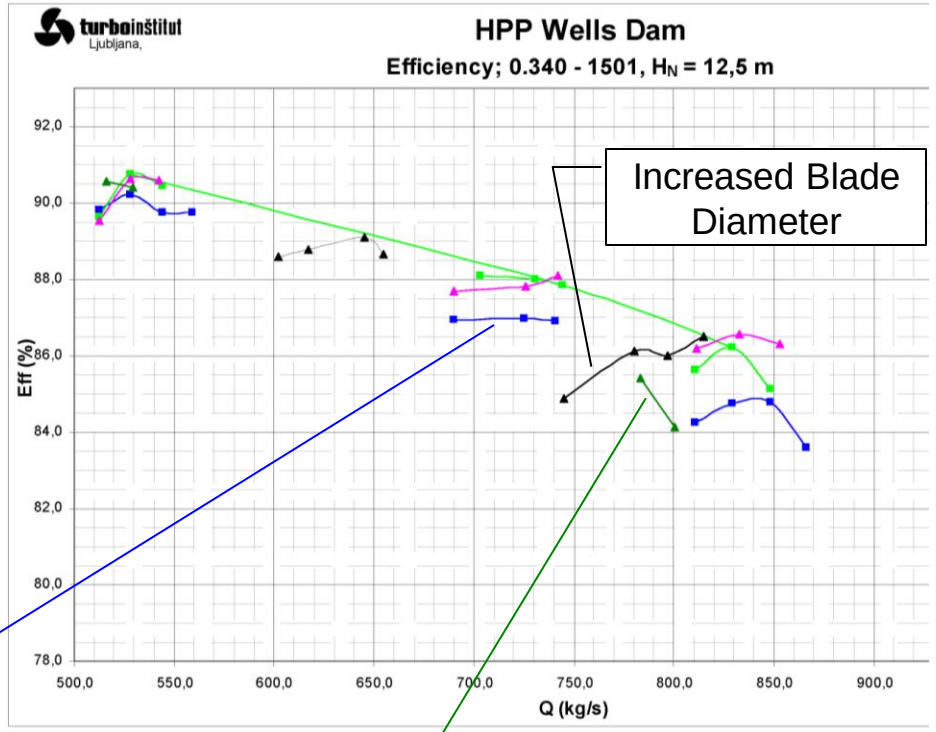
Semi- Spherical



Spherical

Model Testing – Discharge Ring





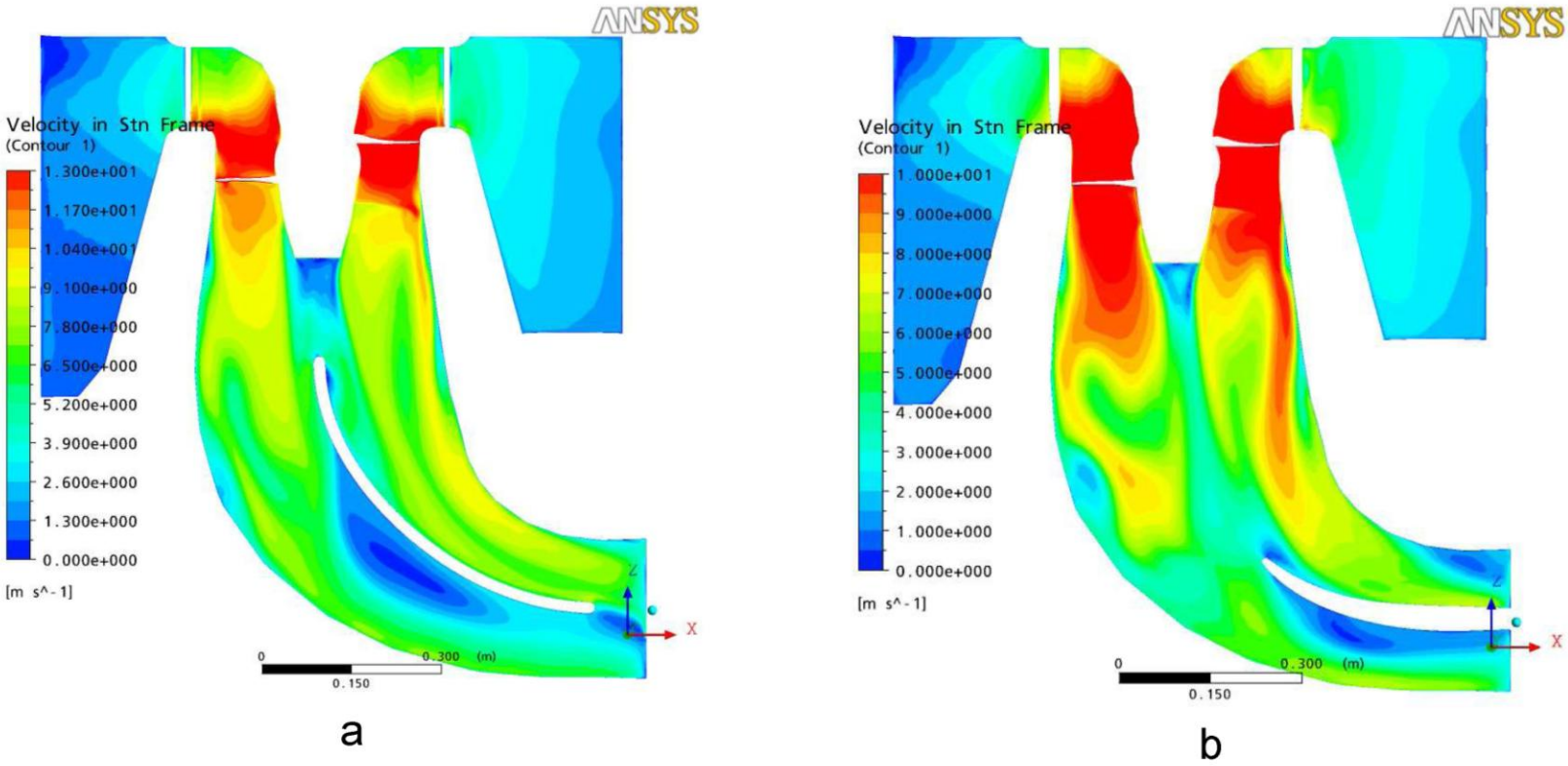
Semi-Spherical

Existing Unit

Spherical

Semi- and spherical discharge ring, and increased blade diameter = no benefit w/o replacing entire runner

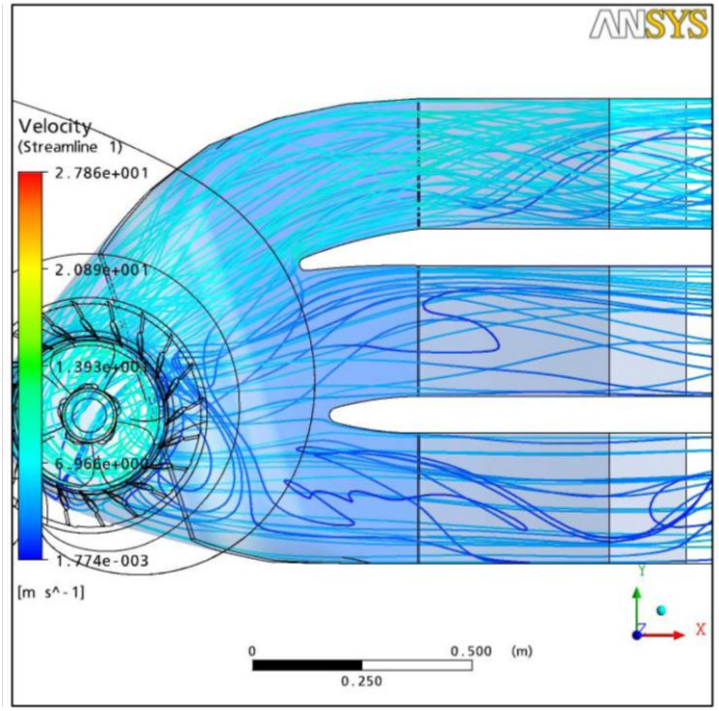
CFD Model Testing – Draft Tube Splitter Vane

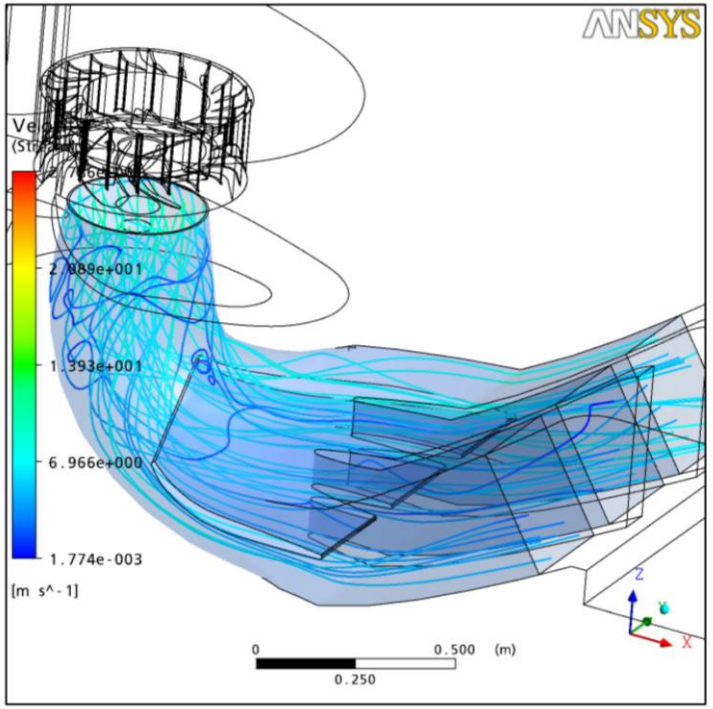


(a) Long vane (b) Short vane

Neither showed improvement, but about 0.5% loss in efficiency = no benefit

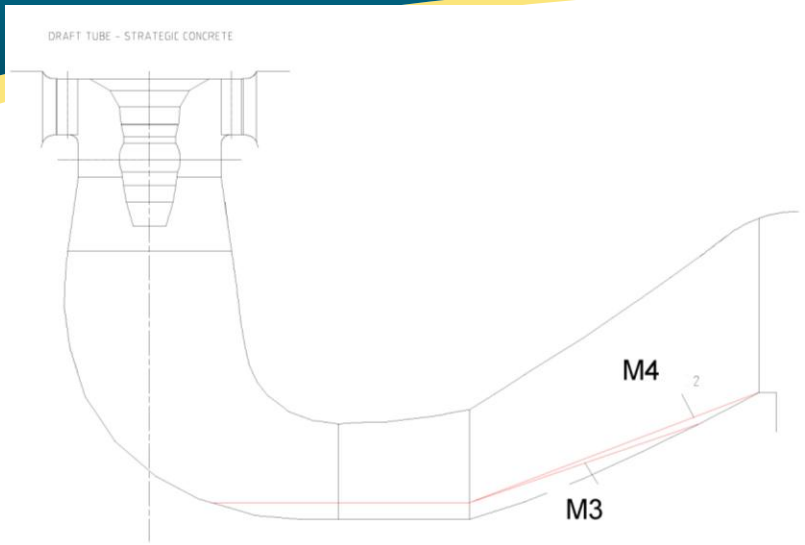
CFD Model Testing – Draft Tube Splitter Vane

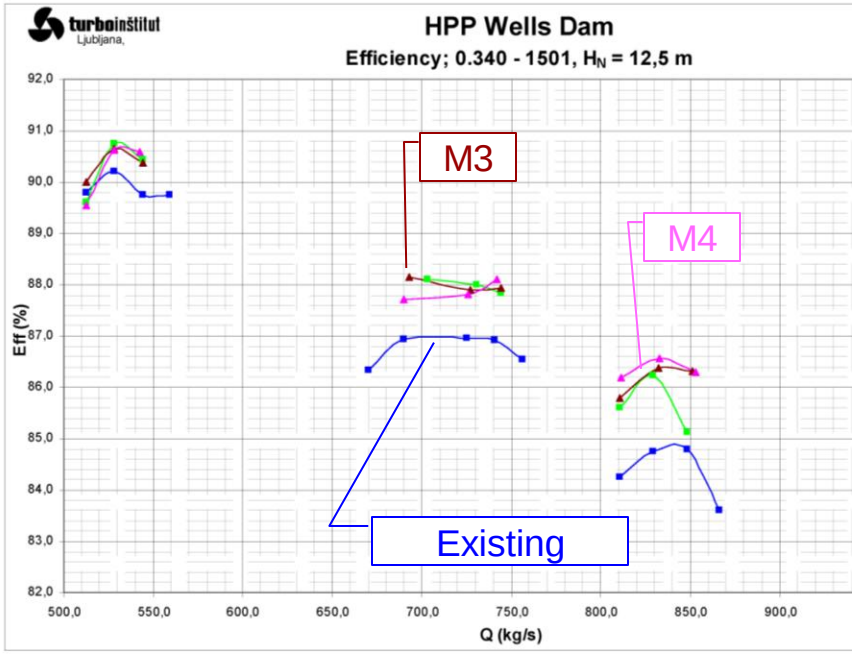




These show CFD runs for the short vane combined with a semi-spherical discharge ring.

CFD Model Testing – Strategic Concrete

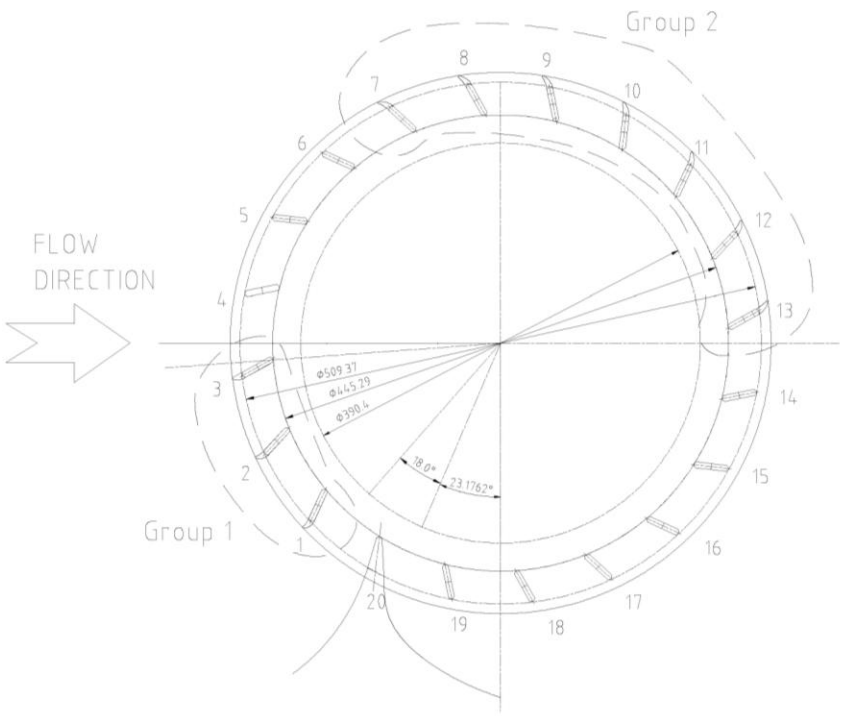


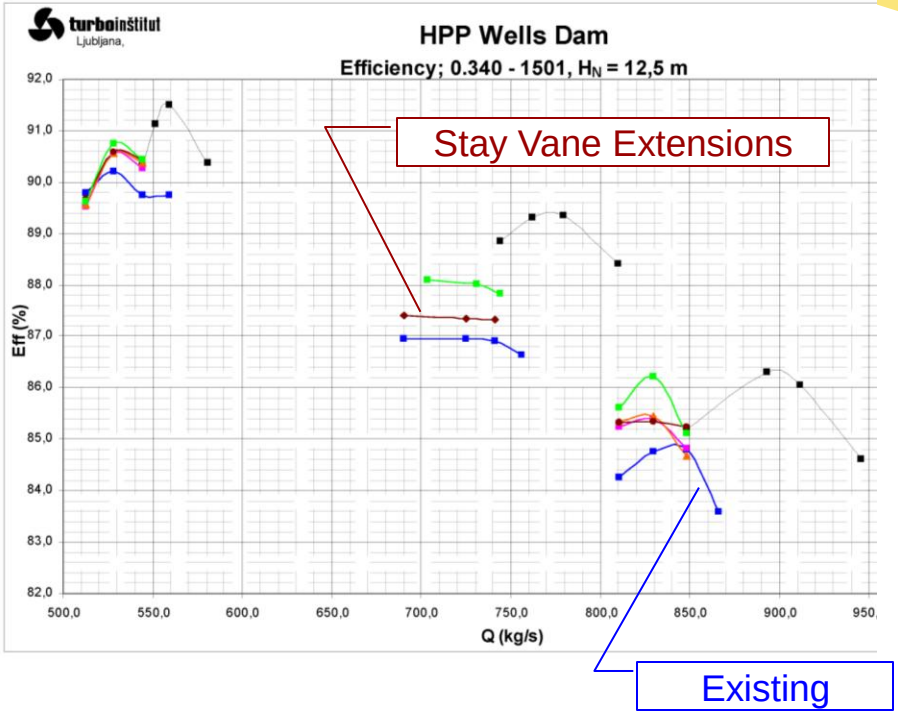


Strategic Concrete:

- Placed in Draft Tube to change velocity and flow.
- Showed promise with possible good cost/benefit

CFD Model Testing – Stay Vane Extensions

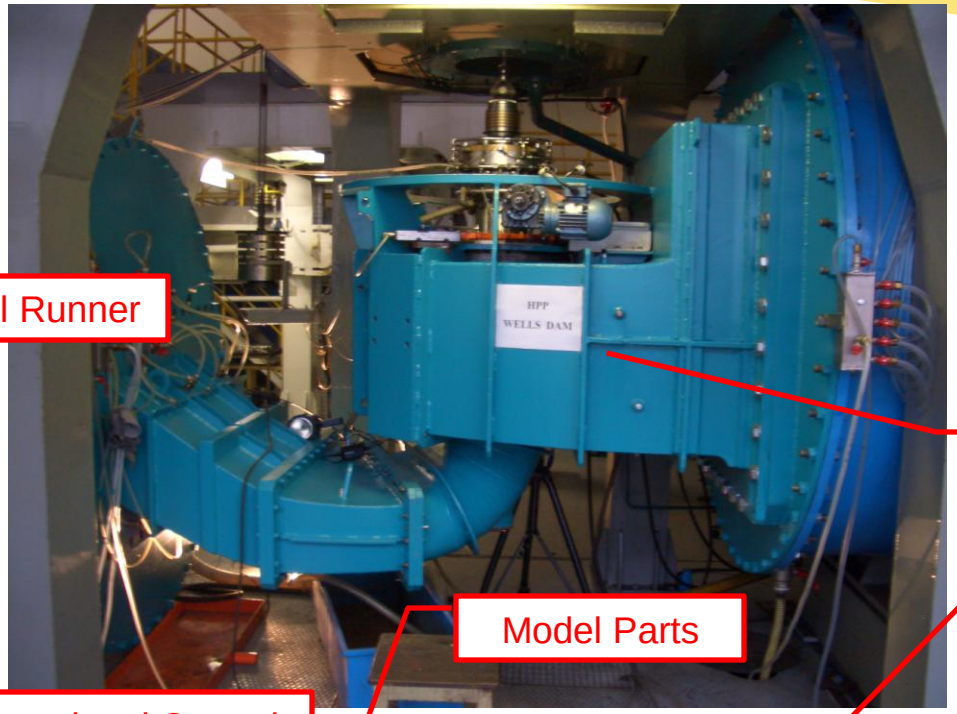




Stay Vane Extensions:
Showed promise – about 0.3%

Scale Model Testing

Collecting Data



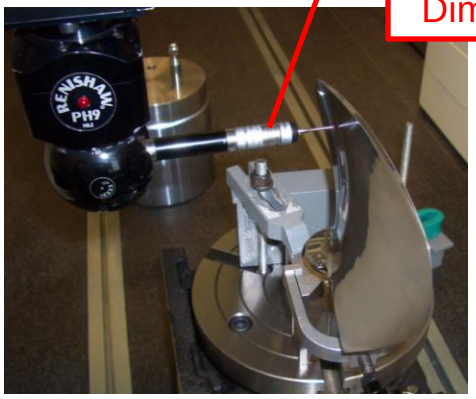
Model Runner

Physical Model: Approximately 1:21 Scale

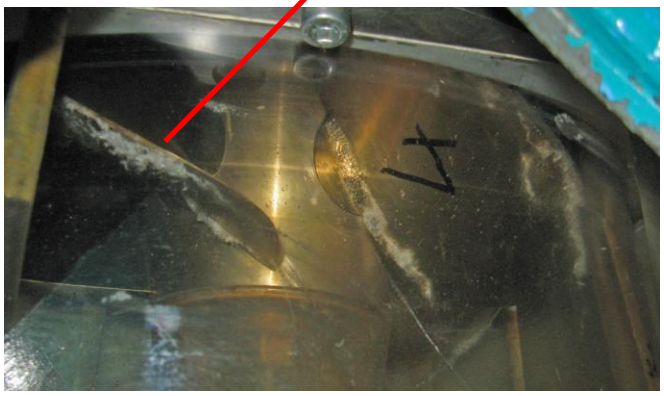
Test Stand

Model Parts

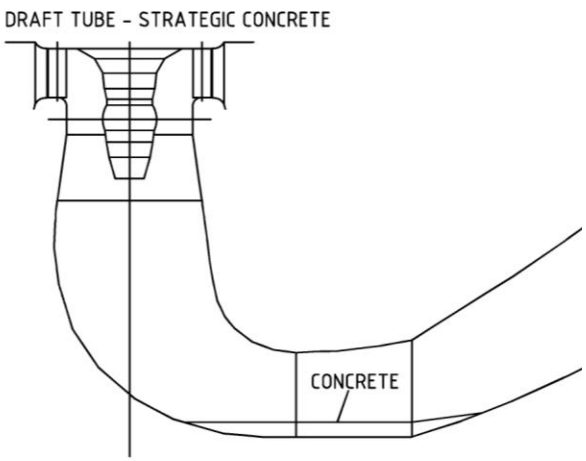
Cavitation Testing

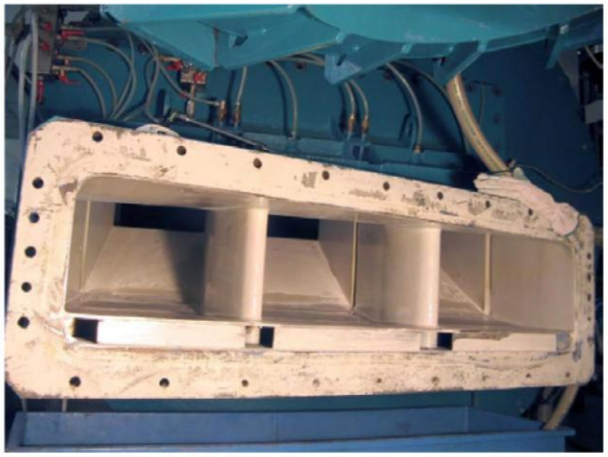


Dimensional Control

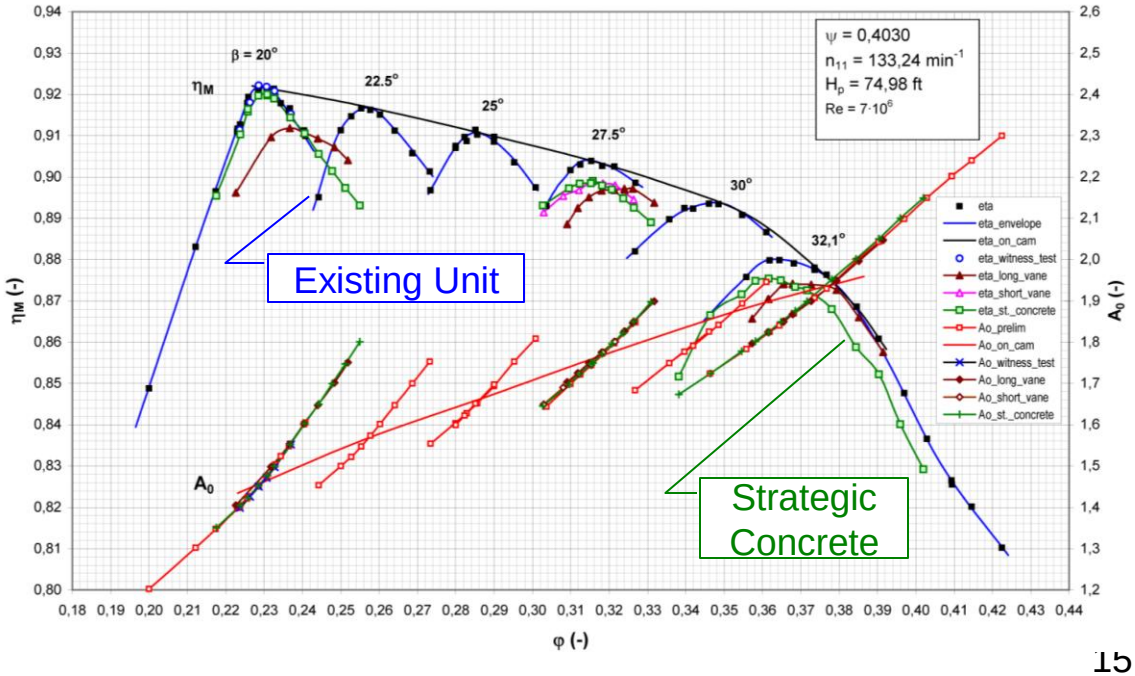


Scale Model Testing – Strategic Concrete



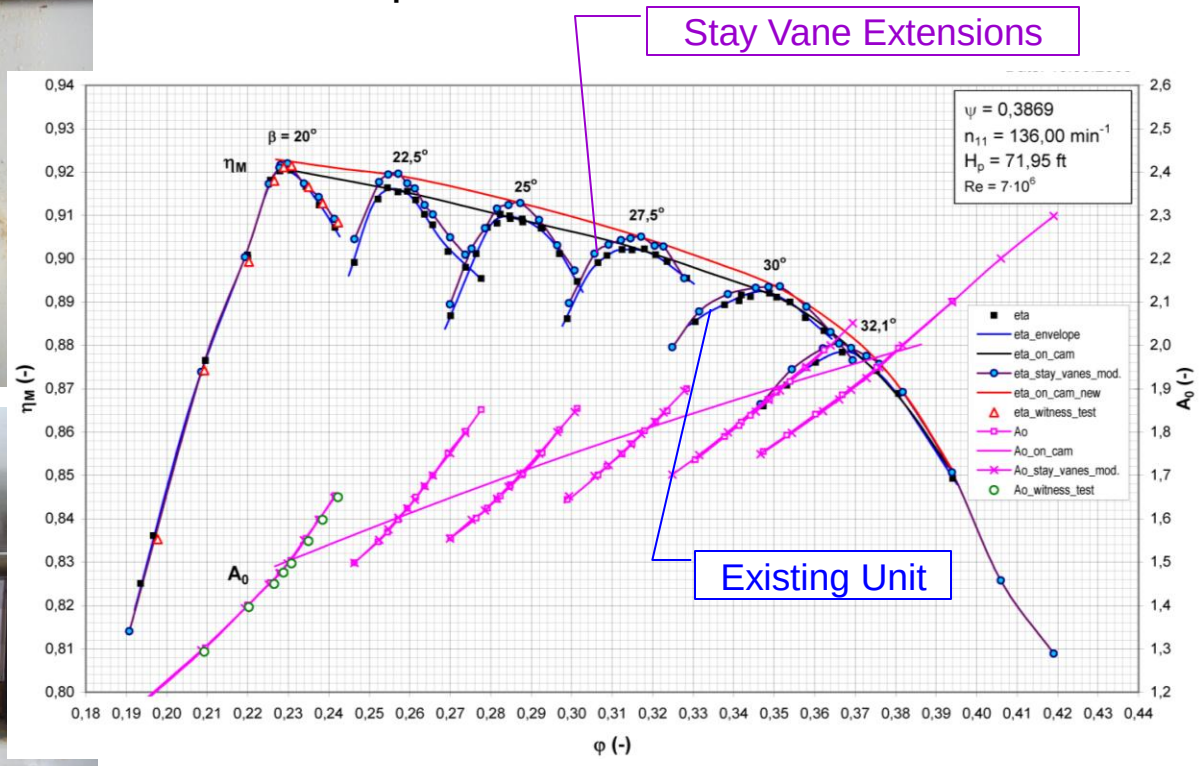


Strategic Concrete did not show increased efficiency



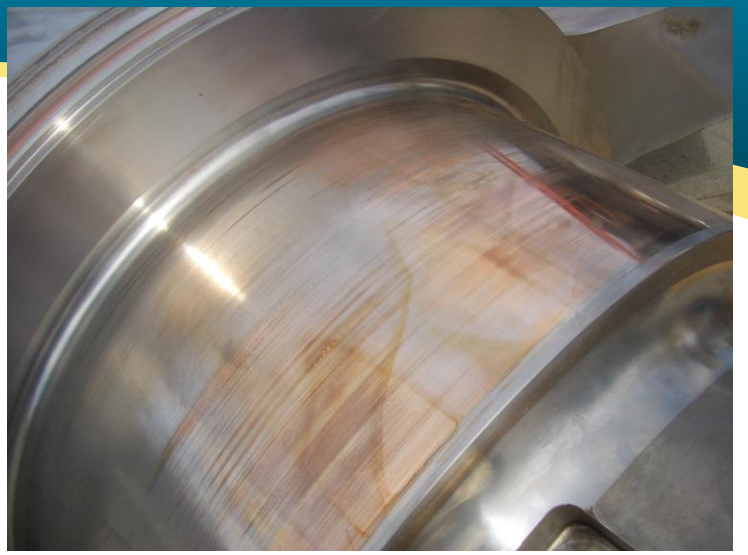
Scale Model Testing – Stay Vane Extensions

Confirmed: 0.3% efficiency gain with estimated positive cost/benefit



However, price negotiations prevented implementation on first Unit

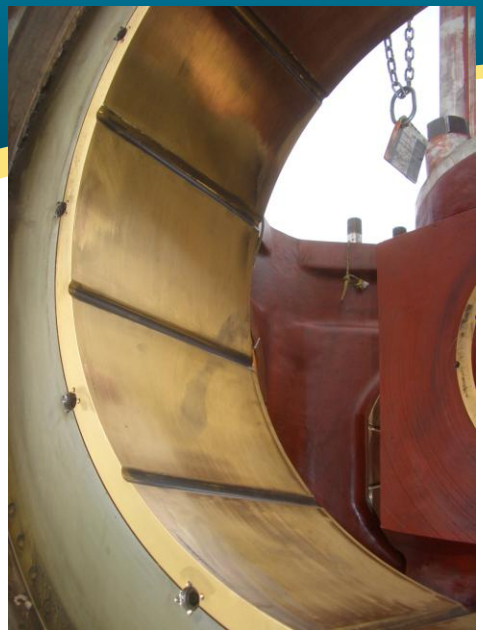
Turbine Disassembly & Inspection



Blades:

- Trunnion surfaces found to have transferred bronze from worn bushings
- Fretting damage in lock ring groove
- Broken bolts from loose-fitting rocker arm keys

Turbine Disassembly & Inspection



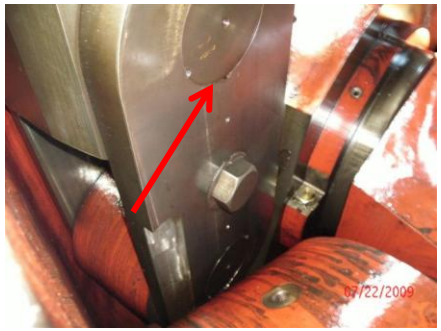
Outer & Inner Trunnion Bushings:

- Found severely worn – causing blade droop
- Likely cause of “Stick-Slip” issue
- Bronze was found to be too soft
- Determined to require replacement

Turbine Disassembly & Inspection

Linkages:

- Fretting and other wear b/t parts
- Set screws b/t link pins and plates all backed out – found broken or in bottom of hub. Caused damage.



Turbine Disassembly & Inspection

Runner Servomotor Guide:

- Found wear, scratches
- Misalignment – not vertical
- Clearances – out of tolerance

Turbine Refurbishment - Blades

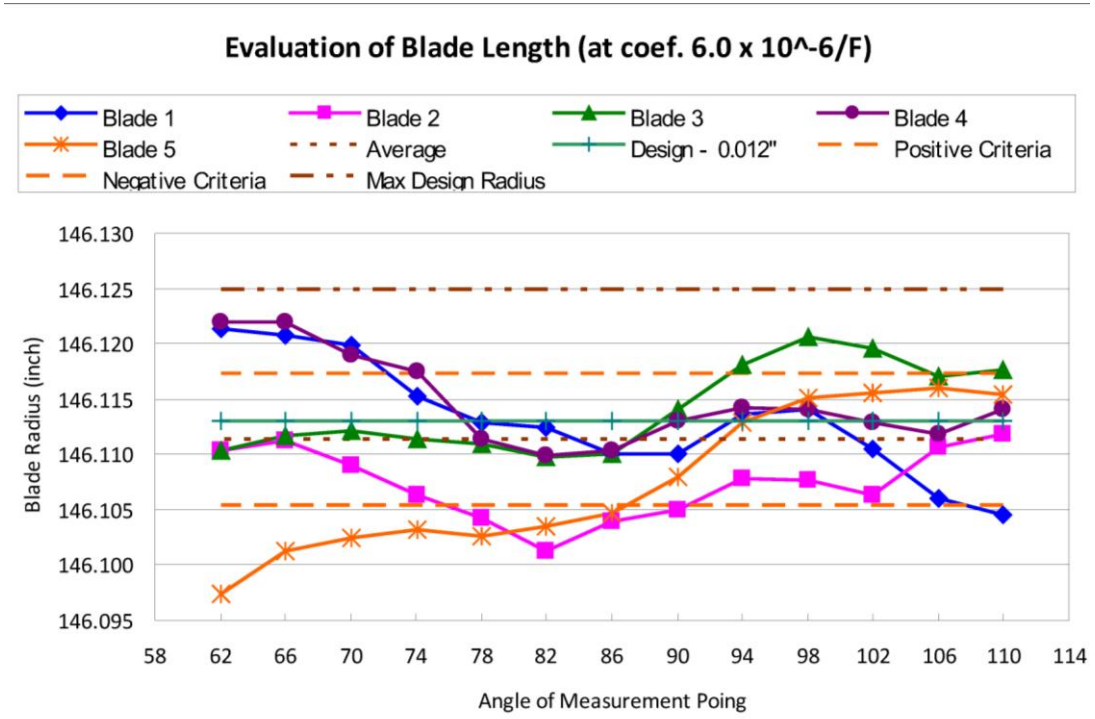
How do you determine and check blade tip diameter and clearance?

- Tolerances of individual components stack up
- Blade weight causes deflection
- Water forces on blades cause more deflection
- Centrifugal forces sling blades outward (75 mph @ blade tip)
- Temperature differences cause thermal expansion

Turbine Refurbishment - Blades

How do you restore the blade tip diameter?

- Ideally machine as an assembled runner
- Contractor had no access to a North American machine large enough for 24+ ft diameter runner
- Account for stack-up of tolerances on components, lock rings to be final adjustment
- Contractor reversed course, deciding to keep lock rings and therefore mechanism tight-fitting
- Got successful results, even without lock ring adjustment.



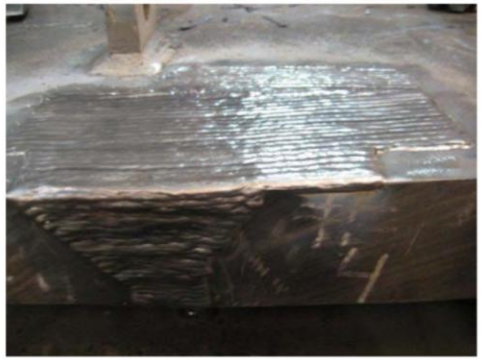
Turbine Refurbishment - Blades

Cavitation Repair

Crack Repair

Blade 3 Complete

Cavitation Repair



Crack Repair

Blade 3 Complete

Blade Periphery Machining

Blade Periphery Machining

Blades:

- Repaired Cavitation damage, lips, cracks
- Skim-cut trunnions to cleanup & new finish
- Welded and machined blade tips to restore runner diameter

Turbine Refurbishment – Bushings

- Researched types of bushings. Settled on Kamatics KAron V coating
- KAron will provide low friction and wear, reduce “Stick-Slip” phonomena
- Replaced inner and outer trunnion bushings, and all link pin bushings
- Line-bored trunnion bushings to final dimension for tight tolerances

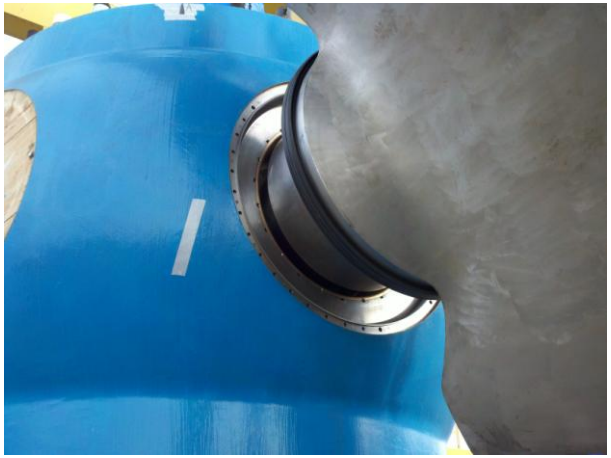
Turbine Refurbishment - Linkages

- New link pin bushings with KAron coating
- Clean-up machining on rocker arms and joint pieces to remove fretting damage, and realign linkage mechanism
- New rocker arm keys – hand fit for tight tolerance
- Redesign - new lock pins to affix link pins to link plates

Turbine Refurbishment – Servo Guide

- Servomotor guide machined for verticality and parallelism
- New bronze plates provided on mating surfaces on upper nosecone.
- Plates machined tapered to provide verticality and parallelism, rather than machining nosecone.

Turbine – Reassembly



Thanks…

Questions?